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ABSTRACT

REPORTED IS A SURVEY OF ASTRONOMY PROGRAMS IN THE EDUCATIONAL AND RESEARCH INSTITUTIONS IN NEW YORK STATE. THIS REPORT SHOWS THAT ASTRONOMY IN NEW YORK STATE IS HIGHLY DIVERSIFIED; BOTH PUBLIC AND PRIVATE SUPPORTED INSTITUTIONS HAVE STRONG, EXCELLENT PROGRAMS. MANY INSTITUTIONS WITH STRONG PHYSICS DEPARTMENTS SEE THE VALUE OF GROWING INTERACTION WITH ASTRONOMY. OUTSTANDING RESEARCH IS BEING DONE IN THEORETICAL ASTROPHYSICS AND IN RADIO ASTRONOMY; THE SAME LEVEL HAS NOT BEEN ATTAINED IN OPTICAL ASTRONOMY. MOST OF THE ASTRONOMERS VISITED ASSERTED THAT BETTER RESEARCH FACILITIES, CENTERING ON A MAJOR OPTICAL TELESCOPE, WERE ESSENTIAL TO CONTINUED GROWTH IN ALL AREAS OF ASTRONOMY AND ASTROPHYSICS IN THE STATE. THE ACQUISITION OF A LARGE OPTICAL TELESCOPE IS CONSIDERED ESSENTIAL TO CONTINUED GROWTH AND INCREASED EXCELLENCE IN ASTRONOMY IN NEW YORK STATE. (ER)

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
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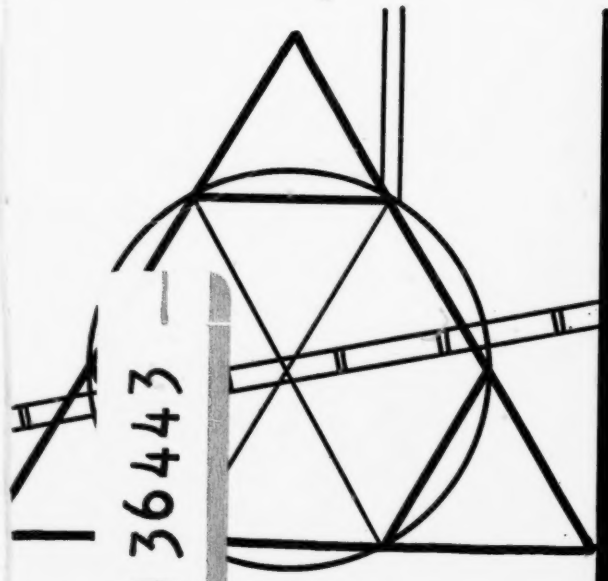
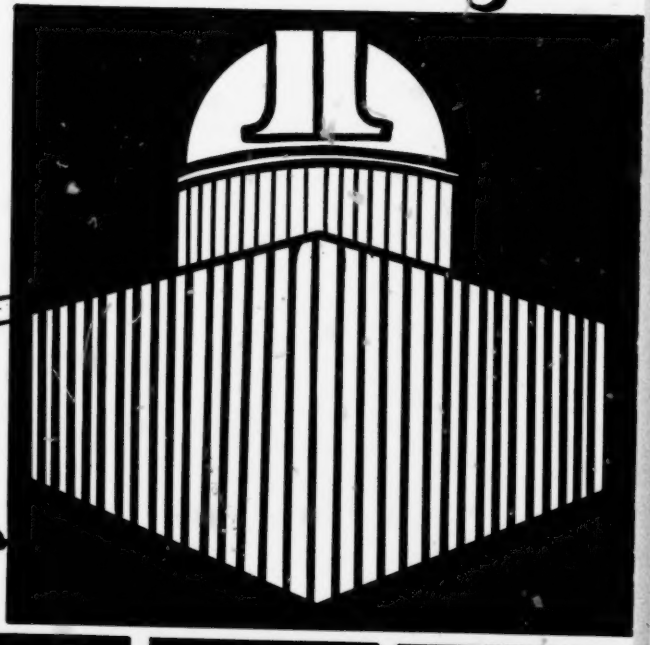
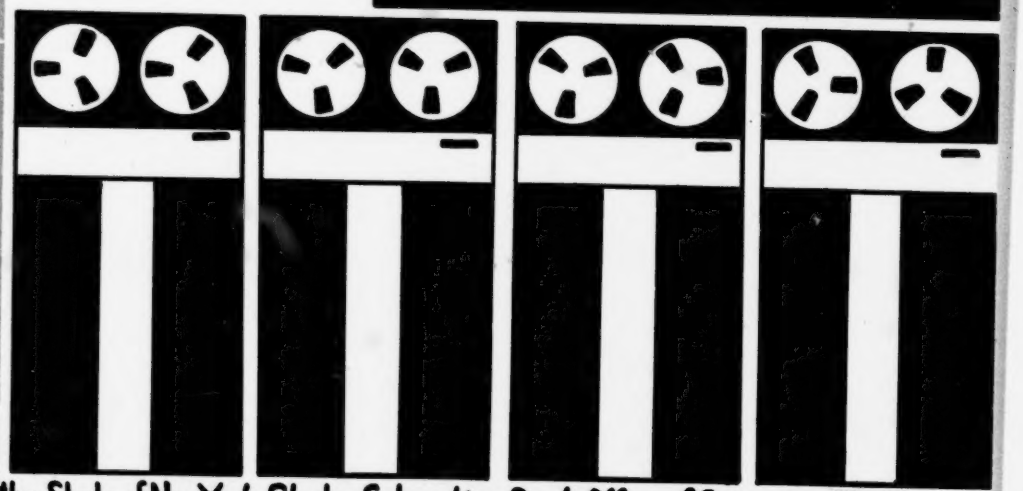
ASTRONOMY IN NEW YORK STATE:

competence and challenge







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THE COVER

designed by Mrs. Austine R. Wood

Across the top of the back and front cover is a sketch of the Spiral Nebulae representative of the observational material of astronomy.

On the left of the front cover is a design representing the feed of Cornell's radio telescope in Arecibo. On the right is the dome of the 24″ reflector of the University of Rochester which is the largest optical instrument in New York. The feed of the radio telescope is in reality far larger than the building housing the 24″ reflector. These two represent the observational tools of the two branches of astronomy, radio astronomy and optical astronomy. Across the bottom of the front cover is a row of computer tape decks representing the IBM 360 computer at Goddard Institute for Space Studies, the largest computer available to astronomers in New York.

On the back cover is an outline of New York State, with the approximate locations of the schools in this report marked by stars.

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Astronomy in New York State
Competence and Challenge
1969

by
Professor H. John Wood
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The State Education Department
Office of Science and Technology

PREFACE

One program of the Office of Science and Technology of the New York State Education Department, is to survey the educational resources of the State in selected areas of science and technology. Under this program the Rensselaer Research Corporation, Troy, New York, contracted to undertake a survey of astronomy programs in the educational and research institutions in New York State.

One can easily extol the history of astronomy as the first science and as a contributor to other sciences. Newton formulated his laws of motion and invented calculus while conducting research to explain the relative movements of the planets; many of the great developments in mathematics occurred through the need to solve problems associated with astronomy; fundamental problems in astronomy and cosmology stimulated Einstein's development of relativity theory; the prediction of mass-energy equivalence in Einstein's theories led to the recognition that nuclear reactions in the stars was the source of their energy; and all are familiar with the role of nuclear energy here on earth.

Advances in this field continue, and some particularly exciting developments have occurred within the last decade. Among the most important have been the discovery of quasars and pulsars, exceedingly intense and sometimes pulsating sources of energy, the explanation of which will tax man's ability to explain his universe. Perhaps equally interesting are the discoveries of phenomena occurring not at cosmological distances, but within the environment of our own planet and throughout our solar system. Astronomers and other scientists associated with lunar and planetary exploration programs have discovered many details about our solar system; the solar wind, the Van Allen belts, solar prominences, and the composition of the moon's surface are among the many (and most practical in view of our national space exploration program) that have been made.

New York State, recognizing the significance of the space program, has established agencies designed to serve her interests in this area; the Atomic and Space Development Authority and the Commerce Department's Division of Industrial Sciences and Technologies. Consideration of the foregoing and more, impelled this survey of our State's educational and research resources in astronomy.

This report on astronomy (OST-7) is one of a series by the Office of Science and Technology. The general objectives of the series* are to contribute to (1) a review of current facilities, personnel, and policies in higher education for teaching and research in science and technology; (2) a clarification of desirable and feasible long-range statewide objectives; and (3) steps in planning to reach these objectives in the near future. The form, content, depth, and emphasis of each report varies with the author who is encouraged to use his personal discretion and judgment in conducting his survey and writing his report.

If recommendations for State action are included in any of these reports they are suggestions of their authors to stimulate discussion and consideration by the appropriate planning groups. Distribution of the report implies no position on such recommendations either by the Department or the Regents.

We are pleased that the author of this report was able to persuade so eminent an astronomer as Professor Bart J. Bok to review the report and to contribute a foreword.

Frank R. Kille

FRANK R. KILLE
Associate Commissioner for Science, Technology,
and Professional Education

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* (OST-1) *Oceanography in New York—A Prospectus*, by John H. Ryther; (OST-2) *A Study of the Engineering Educational Resources in the State of New York*, by Kenneth E. Mortenson; (OST-3) *A Directory of Bioscience Departments in New York State*; (OST-4) *The Role of the New York State Education Department in Science and Technology*, by Vernon Ozarow; (OST-5) *Neurophysiology in New York State*, by Charles Edwards. (OST-6) *Chemistry and Physics Doctorate Production in New York State*, by Vernon Ozarow.

FOREWORD

In 1956 I left Harvard University to take up my appointment as Director of Mount Stromlo Observatory in Australia. I resided there until 1966, when I returned to the United States to become Director of Steward Observatory of the University of Arizona. Upon my return to the United States, I could not help but be struck by the profound changes that had taken place during the interim in the academic picture of the country.

To me, one of the most striking phenomena of the new age was the emergence of many new state university systems, with New York and California clearly in the lead. I could not help but note that the rapidly growing system in New York stressed the training of the young, and of the not so young, at all levels from freshman undergraduate instruction to the most advanced doctoral programs. Among the many activities of the two State University centers which had blossomed forth at Albany and at Stony Brook, are important programs in astronomical research and education.

Great strides were obviously being made in the New York City area, where Columbia University and the City Colleges had expanded and intensified their graduate programs, with increasing emphasis on astronomy and related fields. The new developments in astrophysics at Stony Brook and at the State University in Albany look most promising and the emerging Department of Astronomy at the University of Rochester is one of the best in the country. New centers, such as Yeshiva University, had come into being, and the National Aeronautics and Space Administration sponsored Institute for Space Studies had become a fountainhead for the promotion of research in theoretical astrophysics. The established schools of astronomy at Cornell University and at Rensselaer Polytechnic Institute had expanded. In radio astronomy, Cornell University, with its giant radio telescope at Arecibo, Puerto Rico, had become one of the leading research establishments of the nation.

The new centers for astronomical and astrophysical research in New York State have become favorite places for holding meetings and symposia (among these the TEXAS Symposium!). The constantly increasing flow of advanced research papers by astronomers and astrophysicists in New York State is further proof of the increase in the level of activity.

The university centers in New York State are obviously attracting astronomers from all parts of the world. Nowhere is the close connection between astronomy and physics brought out more clearly than in the researches of the New York State astronomers and astrophysicists.

At present, however, New York State does lack one major facility: a large optical telescope of its own. While it is true that New York astronomers and astrophysicists have been among the most active users of the fine equipment at Kitt Peak National Observatory in Arizona and at the Cerro Tololo Inter-American Observatory in Chile, national facilities are in the end a poor substitute for having one's own telescope in a good viewing location. Such a telescope would provide great incentive to the staffs of the major astronomical centers in the State, it would help attract astronomers and astrophysicists from outside the State to come to its universities on permanent positions, and students beginning graduate work would come to New York State more readily if its universities possessed their own major telescope. The latter point is particularly important because in this field the traditional apprentice approach has proved to be one of the most powerful media for training astronomers of the future. Young people learn very much by working with qualified astronomers as assistants on projects involving the use of large telescopes. In addition, with a large instrument readily accessible, it would be far simpler than it is now for graduate students to go with their elders on observing expeditions where this critical training is obtained.

Reflecting upon the foregoing; appreciating the contributions of the State's strong and viable space physics and astronomy community; one cannot escape the thought that addition to the State's resources of the kind of telescope discussed, would help bring this community from its present strong position to one of preeminence in the world of astronomy and astronomers.

BART J. BOK
Steward Observatory
University of Arizona

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The Lure of Astronomy

Why is astronomy the oldest of the sciences? The answer must be known by every individual who has ever wondered how far away the moon was; what kept the sun so hot; what would it be like to live on Mars; whether man is alone in the Universe.

The objects of study in astronomy belong to every man. Many people today remember the beautiful sight of the close passage of Halley's Comet in 1910. Unlike the laboratory worker who has access to a unique specimen for his experiment, the professional and amateur astronomer can each study in his own way the same star. Therein lies one of the great beauties of new knowledge gained about the star: its universal appeal. As a man's understanding of the universe expands, his wisdom about his place in the universe grows, his awe of the cosmos increases.

Chapter I Developments in American Astronomy

The importance of supporting research in astronomy was recognized early in our Nation's history. A brief account of the subsequent support of work in this field and of the extraordinarily important and vital discoveries of our astronomers, will provide a useful background for the information gathered in the course of this survey.

Support for U. S. Astronomy

Astronomy in the United States was encouraged by President John Quincy Adams. In 1823 he personally offered a gift of $1,000 to Harvard to build an observatory, but no one would match this magnificent gift. In 1825, during his first message as President, he recommended to Congress, support for the establishment of a national observatory. In June 1838, he prepared a congressional report urging that the Smithsonian bequest be used to build an observatory.

Among his writings is this report from a committee which made a study of astronomy in 1842,

> There is no richer field of science opened to the exploration of man in search of knowledge than astronomical observation; nor is there, in the opinion of this committee, any duty more impressively incumbent upon all human governments than that of furnishing means and facilities and rewards to those who devote the labors of their lives to the indefatigable industry, the unceasing vigilance, and the bright intelligence indispensable to success in these pursuits.

Nevertheless, it was not until October, 1957 that the Federal Government responded to President Adams' plea for a national observatory. Working through the Association of Universities for Research in Astronomy, (AURA) it constructed the Kitt Peak National Observatory in Tucson, Arizona.

Before 1957, astronomy in the United States was largely supported by private individuals and private endowment funds. Ormsby McKnight Mitchel was the founder and director of the first major observatory in the United States, the Cincinnati Observatory, built in 1843. The story

of his efforts to obtain funds ($9,000) for the perfect 12-inch lens which he found in Munich, Germany, is indeed remarkable. Citizens of Cincinnati contributed not only their money but their labor and materials to build this observatory. When it was ready for dedication, President Adams, age 76, made the ". . . arduous, hazardous, and expensive undertaking . . ." of the trip from Braintree, Massachusetts to Cincinnati to make a dedication speech. It was indeed appropriate that President Adams, in light of his early and unflagging interest and efforts, dedicate the Nation's first observatory.

It is interesting to note that Professor Mitchel's help was sought by the trustees to draw up plans for the newly incorporated (1852) Dudley Observatory in Albany. Forty-one donors from Albany, 61 from New York City, and 16 from other cities had contributed over $160,000 for the observatory. Land was donated by Stephen Van Rensselaer, the gasworks by Henry Q. Hawley, and an astronomical clock by George W. Blunt. Professor Mitchel gave considerable time and thought to his plans and recommendations for the Dudley Observatory. An early leader in the Nation's efforts in astronomy, the Dudley Observatory remains today an outstanding international leader in astronomy, especially research in space science.

Leander McCormick (who with his brother Cyrus amassed a fortune investing and selling the famed McCormick reaper) gave the funds which built, in 1883 at the University of Virginia, the (then) largest telescope in the world, the McCormick 26-inch refractor.

The aperture race was on. James Lick, a piano and organmaker who had gained a fortune in Gold Rush land speculation, gave money to the University of California for a 36-inch refractor that was in operation soon after the McCormick telescope. C. T. Yerkes funded for the University of Chicago, a 40-inch refractor which remains the largest of its type in the world today.

Great reflectors were also built in the United States early in the 20th century with private or foundation funds. A gift from J. D. Hooker, a Los Angeles businessman, enabled the Carnegie Institution of Washington to acquire the great 100-inch telescope on Mt. Wilson in California. The 82-inch reflector of the McDonald Observatory in Texas was completed in 1939 with support from W. S. McDonald; and the Palomar Observatory in California, supported by the Rockefeller Foundation, was completed in 1947. Today, the 200-inch Hale reflector atop Mt. Palomar remains the world's largest and foremost telescope. It is worth mentioning that this great telescope, with all its power, is neces-

sarily limited in use to a few selected and important projects and, consequently, is used by only a relatively few individuals. The 120-inch Lick reflector, a project funded by the State of California and located on Mt. Hamilton, is the only other new telescope of comparable size. Several years from now, a 158-inch telescope whose construction is supported by the National Science Foundation, will be completed at Kitt Peak National Observatory in Tucson, Arizona. Another 150-inch reflector will soon be completed at Cerro Tololo in Chile with partial support of the Ford Foundation. Despite the availability of these two new major optical telescopes and those already built, the needs of American astronomers for instruments of this kind remain far from fulfilled; a point to be discussed later in this report.

Important and rapid developments have also been made in radio astronomy in the last three decades. Karl Jansky was working for Bell Telephone Laboratories in the 20's, looking for the source of static which might interfere with trans-Atlantic radio-telephone communications, when he discovered cosmic radio noise. Recognizing the importance of this discovery, Grote Reber developed his own radio telescope in his backyard in Wheaton, Illinois to map the sky at radio wavelengths. From this small but profound beginning, new instruments and facilities have developed rapidly. Today, cosmic radio sources are studied at many research stations across the country.

Powerful instruments at the California Institute of Technology, Stanford University, the University of Illinois, the University of Michigan, the Ohio State University, Harvard College, Massachusetts Institute of Technology, and the National Radio Astronomy Observatory are used in important and exciting radio studies. The 1000-foot dish of Cornell University tops the list of these in size of its collecting area.

Most of these major instruments came into being within the last decade, stimulated by the infusion of Federal funds. Thus the history of support for radio astronomy is notably different from that of optical astronomy in both time scale and source of funds.

Modern Research Trends and Opportunities

Some important American discoveries early in the 20th century had a great impact on man's understanding of his place in the universe. In 1920, Harlow Shapley hypothesized, primarily from a study of the distances of globular clusters, that the Milky Way galaxy was much larger than had previously been thought. Perhaps even more important was the conclusion that the sun was not in the center of this disk-like distribu-

tion of stars. As late as 1922, some noted European astronomers were still arguing in favor of a small galaxy with the sun in a central position. Shapley's findings, soon confirmed, are today likened in importance by many philosophers, to Freud's discovery of the unconscious, and Copernicus' discovery that the earth was not in the center of the solar system.

During the 1920's Edwin Hubble at Mt. Wilson Observatory established the extragalactic nature of the spiral nebulae, now called galaxies, and V. M. Slipher at Lowell Observatory discovered the red-shift distance relation for these external galaxies. Thus, our picture of the expanding universe came into being as a result of the great efforts in astronomy in the United States in the early part of the 20th century.

Today, unprecedented opportunities for new discoveries and new answers to old questions present themselves in research astronomy. The enigamatic quasars possibly lying at the edge of the universe may provide new understanding of the physical history of the universe. The energy output of the pulsars is enormous considering their probable small size and large distances from the earth. As new observations become available, astrophysicists and high-energy physicists are collaborating to think out the physical problems suggested by these remarkable astronomical discoveries. If quasars do lie at cosmological distances, new insights and new physical laws may well be required to explain their enormous energy output.

An unusual opportunity for future astronomical research lies in observations made from the Southern Hemisphere. The early blossoming of astronomy occurred in the Northern Hemisphere and thus most observations have been made from observatories in this location. However, to an astronomer who has spent time viewing the southern sky, it is clear that some of the universe's most important regions, the Carina nebula, the nearest star Proxima Centuri, the nearest neighboring galaxies, the Large and Small Magellanic Clouds, and the central regions of the Milky Way, in Sagittarius and Scorpius, hardly rise above northern horizons—and thus remain unseen by the best telescopes (and most astronomers) in the world, those of the Northern Hemisphere observatories.

The situation will not remain this way for long. Five European nations have combined to build an observatory near La Silla, Chile. The European Southern Observatory will greatly strengthen and invigorate astronomy and astrophysics in cloud-bound Europe. Russian scientists have started small projects in the Santiago and La Serena areas. They and others have found the Chile sites to be vastly superior to similar sites

in Australia and South Africa. The AURA corporation is developing an observatory near La Serena in Chile. This Cerro Tololo Inter-American Observatory will serve the needs of U. S. and Chilean astronomy much as Kitt Peak provides facilities for U. S. Northern Hemisphere astronomy. Great Britain and Australia are jointly erecting a 150-inch reflector in Australia.

In addition to providing the opportunity to study previously inaccessible but familiar objects, the southern observatories are proving valuable adjuncts to space age astronomy. X-ray sources newly discovered from rocket experiments are presently being monitored at Cerro Tololo Inter-American Observatory. Quasars and new pulsars found by Australian radio astronomers are also under study by the American astronomers in the Southern Hemisphere.

Chapter II Graduate Training of Astronomers

With this brief sketch of the development of astronomy in the United States, let us focus on the immediate goal of this study: a survey of astronomy programs in New York State. First of all, it is important to recognize the need for observational experience in the training of astronomers.

The formal requirements for graduate degrees in astronomy typically follow the practice of other physical sciences: formal courses, comprehensive examinations, and thesis research. However, an important difference exists; it is necessary for the observational student to gain his training and research data at facilities relatively remote from the university. In contrast to a physics student, who may walk down the hall to his laboratory, the astronomy student must travel 10 to many thousands of miles to the observatory. A number of excellent students who have held fellowships, without teaching or research commitments, throughout their college and graduate school years have expressed the feeling to this writer that they would have had a more balanced education had they been research assistants. This assignment would have provided additional apprentice-like experience over that gained with their research professors.

There will continue to be a great need for formal, graduate lecture courses at all levels. Certain topics, for example, theoretical astrophysics, may well be better suited to lecture situations than to seminar or tutorial instruction. Nevertheless, in observational and laboratory astrophysics, including radio astronomy, contact with actual research is increasingly important.

This trend of increased student participation in research puts new demands on the astronomy department to have an active and well-balanced research program. Travel funds ought to be available so that students can accompany faculty members on research trips, both as assistants and later to carry out their own dissertation projects. Postdoctoral fellowships greatly increase the effectiveness of a research program and give the recipient valuable experience in the field of his choice.

Chapter III

Astronomy in New York State Institutions

This study gives information on the facilities, personnel, programs, and plans for astronomy in the various institutions of higher education in the State of New York. Since any educational institution is, of necessity, flexible in its plans and programs in response to student, faculty, and financial requirements, some of the programs and plans discussed here will be outdated by the time this report is published. Recent Federal cutbacks in research support have directly or indirectly affected virtually every institution visited.

It was not possible to cover all institutions offering astronomy courses. Some schools which presently have small programs came to the writer's attention because of their collaboration in the New York Astronomical Corporation and their interest in future astronomy programs at their institutions and in the State. It should be noted that the New York Astronomical Corporation serves as a coordinating body for the development of its members' interests in astronomy and space science.

A. *The American Museum of Natural History—Hayden Planetarium*

The Hayden Planetarium is one of the oldest and largest in the United States. Its major source of financial support is the admission fees from the public. Last year attendance was about 600,000, of which 200,000 were school children. There is no financial support from the American Museum of Natural History, endowments, or public monies.

Major equipment at the Planetarium consists of the Zeiss projector used in their specialized instructional programs in astronomy and also in popular presentations to the general public. A small research installation in radio astronomy is operated on Long Island with major research emphasis on the bursts of radio emission from the planet Jupiter. This project is supported by the Planetarium.

The Planetarium offers a number of courses in the area of teacher and adult education with some financial support from the Bureau of Science Education of the New York State Education Department. The National Science Foundation has for a number of years supported summer institutes for talented high school students. The present staff includes three professional astronomers with two interns. The interns may

eventually become science educators and perhaps planetarium directors. The Planetarium hopes in the future to become a degree-granting institution in the field of science education.

This institution has served for years as an interface between professional astronomy and the mass media. In this function, responsible and accurate reporting of new discoveries to the public have been made on behalf of the research scientist and his institutions.. Newspaper news services and the major television and radio networks usually consult the Planetarium about the latest findings in astronomy and space science before publishing their statements.

B. *Brooklyn College of the City University of New York*

Primarily engaged in a physics-astronomy undergraduate teaching program, Brooklyn College carries out small research projects. Three professors are involved in the teaching and research programs. A 7-inch aperture refracting telescope is housed on the roof of the science building at the college. The telescope is equipped with a photoelectric photometer and a 35 mm camera for direct photography. A small transit instrument is housed in a neighboring flat-roofed structure. The telescope has been used recently in a small program of infrared lunar photography.

Presently two IBM 1620 computers on the campus, are used by faculty and students for small computer-oriented projects. Faculty members conducting major research in theoretical astrophysics use the large computer facilities at the Goddard Institute for Space Studies.

C. *The City College of the City University of New York*

The Physics Department at City College has a growing program of research and has initiated a graduate program in space physics and astrophysics. Three full-time faculty members are active in those areas of research and three adjunct faculty members share their time with the Goddard Institute for Space Studies. Major research programs at City College are in the specialized areas of stellar atmospheres, stellar interiors related to very massive stars, and the effects of nuclear reactions on the composition and physical properties of neutron stars. In addition, studies in ionospheric physics and the interaction of the radiation belts with the terrestrial atmosphere are carried out. The program will be continued as part of a physics major with increasing emphasis on graduate level courses. Most theoretical calculations are carried out at the Goddard Institute for Space Studies in New York.

D. *Colgate University*

The Department of Physics and Astronomy at Colgate University has one astronomer at present. Existing facilities include a new 16-inch reflecting telescope equipped for cassegrain and Newtonian photography. A micro-densitometer and other small telescopes are utilized for data reduction and demonstration purposes. The students and faculty often utilize a GE Model 635 computer at the Rome Air Development Center for astrophysics and data reduction problems. The university uses the computer on a time-sharing basis employing remote terminals.

Major research areas include observational studies relating to star formation. The astronomer utilizes telescopes at Kitt Peak National Observatory and at Yale University Observatory for gathering data. The star formation studies are supported by research grants from the National Science Foundation. While no graduate program in astronomy presently exists at Colgate, a possibility of future Master's-level cooperation with Syracuse University does exist. Several astronomy-oriented physics majors have gone on to acquire the Ph.D. in astronomy at other institutions.

E. *Columbia University*

Columbia University's astronomy programs are supported by Federal and university funds. Research support in recent years has come from the National Science Foundation, National Aeronautics and Space Agency, and the Air Force Office of Space Research.

The facilities at the university campus include a small 12-inch Clark refracting telescope for demonstration and teaching purposes. A new 24-inch reflecting telescope has recently been installed in an observatory approximately 50 miles from the university campus. This telescope, in a relatively clear site in New York State, will serve to stimulate the observational programs at the university by its accessibility.

Columbia University and Yale University operate the Yale-Columbia Southern Observatory in Argentina. The major program at this observatory is an astrometric survey of the southern sky with a 20-inch twin astrograph. The astrometric program is about 65 percent completed and will begin to show main results about 30 years from now. Some intermediate results are now available from the photographs. Research on variable stars is carried out utilizing the astrometric plates. The images are measured with iris photometers at Columbia. However, the Argentina Observatory has limited usefulness as a research tool for

the majority of staff members at the astronomy department because of the specialized scope of the program.

The major computer center at Columbia University houses IBM equipment. The Department of Astronomy, presently strong in theoretical astrophysics, makes use of the computer center for theoretical calculations. In addition, the IBM 360/95 at the nearby Goddard Institute for Space Studies is utilized by Columbia astronomy staff members. At present, there are 13 faculty and staff members in the department. Their research interests range over the entire spread of fields in observational astronomy and theoretical astrophysics.

The instructional program of the Department of Astronomy at Columbia leads to the undergraduate major in astrophysics and the doctorate degree in astronomy. Eleven undergraduate courses and 13 graduate courses, including two in research instruction, are offered. In addition, a strong program of physics course work is required of the astronomy graduate student.

The recently established site in New York State with its new 24-inch reflector will allow the department to undertake new programs in observational astronomy and further strengthen itself in that direction. To better balance observational and theoretical astronomy, two future staff positions may be filled with observational specialists. Programs in spectroscopy of the brighter stars will be carried out with a coude spectrograph when the new reflector is completed. Narrow-band photometry will also be done at the new observatory. Plans are to have nine full-time academic faculty, 12 research associates, and approximately 22 full-time graduate students in 6 to 7 years.

F. *Cornell University: Arecibo Ionospheric Observatory*

Although the Arecibo Ionospheric Observatory (AIO) is a part of the Cornell University Center for Radiophysics and Space Research (CRSR), we will report separately on the programs at the radio/radar observatory in Puerto Rico and at the CRSR Space Science Building in Ithaca. The major research instrument at Arecibo, Puerto Rico is a 1000 ft. aperture radio/radar telescope constructed through a contract by the Cornell University Astronomy and Engineering staffs for the Air Force Advanced Research Projects Agency (ARPA). The initial cost of the instrument was about $9 million. Although the Observatory has been supported by the Air Force, no secret or classified projects are carried out with its telescope. New funding is anticipated from the National Science Foundation.

The instrument is extremely versatile since several experiments can be carried out simultaneously. For example, it is possible to transmit and receive on radar systems with concentric feeds at widely disparate frequencies (40 mHz and 430 mHz) simultaneously. The feeds can be moved along a curved track, which in turn rotates under a stationary triangular platform. Thus the instrument can be aimed 20° in any direction from the zenith.

The Observatory was built at a near equatorial location so that during part of the year the sun, the moon, and the planets pass nearly overhead through the antenna's cone of view. Thus, radar studies of the planets Mercury, Venus, and Mars can be carried out. Radar maps of the moon have been made.

As a passive instrument the dish can be used to study cosmic radio sources in the 40-degree band centered on 18° north latitude. The earth's rotation allows east-west sky coverage. In studying the earth's ionosphere, the concentric feeds and dual radars allow studies of the heating of the ionosphere. One radar is used to heat the atmosphere and the other to study the ionospheric changes caused by the heating.

The AIO radio telescope is used in conjunction with two computers. An SDS (Scientific Data Systems) digital computer is used to automatically track sources through the cone of view of the telescope. The computer actuates motors on the feed structure to move the carriage houses supporting the feeds so that the radio source will stay in the field of view for several hours as the earth turns. For approximately 50 to 70 percent of the operating time of the instrument, a CDC (Control Data Corporation) is used for on-line data collection and preprocessing. The remainder of the time, the CDC 3200 is used in processing magnetic tapes recorded earlier at the telescope.

There are 125 staff members at AIO. Of these, about 100 are Puerto Rican technicians and support personnel and approximately 25 are scientific and technical staff from Cornell and the mainland United States. Of the 20 Ph.D.'s presently on the staff, seven are carrying out research in ionospheric physics. Four scientists are involved in radar studies and nine are involved in radio astronomy programs. The distribution of telescope time among these three fields is approximately 33, 10, and 50 percent. Numerous graduate students come to Arecibo from Cornell to assist in the radio and radar studies there. These students have opportunities to use the equipment for dissertation research. In addition, the Observatory welcomes guest investigators from all over the world who have related projects.

In radio astronomy, long base-line interferometry over thousands of miles has been established by cooperating observatories with no real time electrical connection between them. The outputs of the Arecibo radio telescope and the other cooperating telescopes (for example, the 140-foot dish of the National Radio Astronomy Observatory at Greenbank, West Virginia) are tape recorded with accurate time markers included on the tape. At a later time, the tapes are combined in a computer and the very high resolution of a hypothetical dish antenna thousands of miles in diameter is simulated. New radio sources have been identified, and during the past 6 months a great deal of data on source size and structure has been obtained for some 500 cosmic radio sources.

In the radar programs, the most recent measurements of Venus at inferior conjunction have shown several new enhanced radar reflecting regions. Some of these regions appear faintly circular in nature, similar to lunar craters.

Several radio astronomy programs on planetary nebulae and ionized hydrogen regions have been carried out utilizing the radio astronomy receiver at AIO. New information on the physical nature of these interesting objects has become available as a result of this work.

A visit to the site in Puerto Rico impresses one with the high degree of ingenuity in design and operation of this large instrument. The instrument is built entirely with suspended cables supporting, not only the feed platform at the focus but also the surface of the dish itself.

There are numerous schools for electronics technicians in Puerto Rico. Thus many of the supporting technical staff for the Observatory are local residents. Among them are professional engineers able to cope with the technical problems presented by this unique instrument without a great deal of additional training. In addition, since the staff lives in the area surrounding the Observatory, the security of the instrument is insured by their natural interest in the facility and understanding of the operation.

In the fall of 1967, a committee chaired by R. H. Dicke of Princeton University concluded that the improvement of the AIO reflector surface was more important than other proposals then considered for the advancement of radio astronomy in the United States. If funded, the new reflector surface would have a finer mesh or a solid surface rather than the ½-inch square mesh which now defines the 1000 ft. spheroidal shape. The dish would not only have a finer structure, but a more accurate shape. This would enable the large reflector to operate at higher frequencies and hence at shorter wavelengths. For example, the 21 cm

hydrogen line at 1420 mHz could be effectively observed if the dish were so improved. The goal of the proposed project is to improve the dish so that wavelengths as short as 10 cm can be studied with high angular resolution. The cost of such a surface should be approximately $3.5 million. The suspension system of the feed structure would also have to be improved. At the time of this writing, funds have been granted Cornell University to carry out an engineering design study on the optimum way of achieving these results.

Two other projects are funded and under construction. A bistatic radar located on the east tip of Puerto Rico, 100 km from the AIO site will utilize 14 cylindrical paraboloidal dishes. This radar, used with the 1000-foot dish will give 1 km height resolution for ionospheric studies. The AIO dish will look straight up and the bistatic radar will look at an oblique angle to the column of atmosphere illuminated by the major instrument. Another project is the planetary interferometer. In order to resolve the natural north-south ambiguity in radar studies of Venus and other planets, a small 100-foot aperture dish will be located approximately 10 kilometers away from the AIO site. This small dish, when operated as a radar in conjunction with the AIO 1000-foot radar will yield necessary information to provide unambiguous radar maps of the surfaces of the planets.

New discoveries concerning the nature of the pulsars have recently been made at the Arecibo Observatory. The longer-period 1 second pulses have been shown to be made up on continuous, shorter-period repetitive pulses. These studies by faculty and graduate students presently continue at an intense level at AIO. New breakthroughs in this very exciting field seem to occur almost daily.

In summary, the Arecibo operations of Cornell University have proven to be very effective in gathering scientific data of a unique variety at a relatively small cost compared to similar installations. The site was chosen on a number of criteria: it had to be close to the earth's equator, relatively free of radio interference, and capable of drawing upon a talented native population. No doubt, the great scientific productivity of the observatory in three different areas of astronomy and space research was a major factor in the Dicke Committee's conclusion that AIO should be funded for the solid surface.

G. *Cornell University: Center for Radiophysics and Space Research*

The Center for Radiophysics and Space Research (CRSR) of Cornell University at Ithaca is an organization within the university which enables professors from several disciplines to utilize instrumentation and

technical staffs assembled with a common objective. It was established for facilitating and promoting research and graduate education in the branches of science related to radiophysics, astronomy, and the study of space. Normally about 20 professors and research associates are members of the CRSR. A recent list named 23 members of CRSR in the fields of engineering, physics, and astronomy.

Among the facilities located in Ithaca in the new Space Science Building are the Lunar Surface Laboratory and the Infrared Astronomy Laboratories, a machine shop, scientific and administrative offices, and facilities for graduate study. In the vicinity of Ithaca are the Danby and Zeman Rd. Radio Astronomy Laboratories, cosmic ray field stations, and the radio star scintillations field station. Additional university facilities include a computer center, a nuclear reactor laboratory, a shock tube laboratory, the nuclear studies laboratory with its 10 BEV synchrotron, and the university library system.

Major programs in lunar studies, infrared astronomy, and exobiology are underway at Cornell. The newly formed Laboratory for Planetary Environments and Exobiology has been established in the Space Science Building for research on the physics and chemistry of planetary atmospheres, the origin of life on earth, and the possibility of extraterrestrial life. Thus increasing CRSR contact with the chemistry and biology departments of Cornell University will come about. Research on the lunar surface is carried out in the laboratory by studying the photometric properties of various simulated lunar soil samples. The Cornell laboratory has been chosen by NASA to receive one of the lunar samples being collected in the Apollo moon-landing program.

The Infrared Astronomy group has successfully flown several small rockets with IR-detector telescopes. This program is extremely sophisticated involving complete cryogenic cooling of the telescope and detectors. Remarkable new cosmic IR sources have been discovered and studied in this program. In addition, a graduate student is carrying out a ground-based IR program with a very-high resolution Fabry-Perot spectrum scanner. The observations are made at Kitt Peak National Observatory.

In September 1964, Cornell University and the University of Sydney in Australia entered into an international cooperative program in radio astronomy and the space sciences. The Cornell-Sydney University Astronomy Center (CSUAC) with headquarters at Cornell includes members from Cornell's Center for Radiophysics and Space Research, and from Sydney's School of Physics, Astronomy, and Nuclear Research and

its School of Electrical Engineering. Coordinated astronomical observations are being carried out between the two continents.

The large Millscross radio interferometer in Australia is utilized in the study of cosmic radio sources which can also be reached with the 1000-foot dish in Puerto Rico. Several postdoctoral research associates from the University of Sydney are on the CRSR and AIO staffs and there are frequent interchanges of faculty members between the two universities. Several graduate students from Sydney were on hand in Puerto Rico when the writer made a site visit in August 1968.

Graduate education is carried out with degrees awarded in the fields of electrical engineering, applied physics, and astronomy. While the degree shows the discipline of the major advisor, the advisor is usually a member of CRSR and the students find graduate assistantships, fellowship support, counseling services, and office space with the CRSR. There is a program leading to an undergraduate major in astronomy, a master's program, and the Ph.D. program as outlined above.

In summary, the CRSR has developed, along the lines of its objectives, as an interdisciplinary center for research in the space sciences. The departments of physics, astronomy, engineering, chemistry, and biology are directly involved in space science research as a result of the CRSR. Most of the AIO data reduction and discussion of results is carried out at Cornell. Thus the CRSR at Cornell can be viewed as the main headquarters for the operations in Puerto Rico and as a joint headquarters of the international operations in CSUAC.

H. *Fordham University Astronomical Laboratory*

The Fordham University Astronomical Laboratory is a one-man research effort which operates with financial support from the National Science Foundation, the Vatican Observatory, and Fordham University. The major research effort consists of the discovery (and the publishing of light elements and light curves) of variable stars in the Cygnus Cloud. A collection of approximately 3000 plates from the Vatican Observatory is on hand at the university. Supplementing the Vatican collection are more than 500 other plates from the Mt. Wilson and the Palomar Observatories, Hamburg Observatory, Heidelberg Observatory, and Harvard Observatory. Twenty-five major research papers on the long-period variable stars have been published in the Vatican Observatory publication *Ricerche Astronomiche*. When supplementary observations are needed to complete a light-curve, they are usually obtained through the cooperation of the Hamburg Observatory.

No telescopes are available at the Fordham University campus. The large plate collection was obtained with the Zeiss 16-inch quadruplet at the Vatican Observatory at Castel Gandolfo. No plans to expand the program were anticipated at the time of the visit.

I. *Goddard Institute for Space Studies*

The Goddard Institute for Space Studies conducts theoretical and experimental research in astrophysics, planetary physics, and atmospheric physics. It is located near Columbia University in New York City. The Institute was originally conceived at the National Aeronautics and Space Agency's Goddard Space Flight Center in Maryland, and the Institute remains a part of the Goddard Center.

The major research instrument is a large IBM Computer Model 360/95. Another similar computer is located at the Goddard Space Flight Center and is used directly in controlling various spacecraft launches and operations. The computer is said to be approximately 50 times faster than the conventional IBM 7094 and has considerably greater memory capacity.

Other equipment available for research use at the Institute includes a balloon-borne telescope used by one of the Institute members to survey the sky in the infrared spectral region. The electronics for the IR detector were developed in a laboratory at the Institute and the balloons are flown from the national ballooning facility in Palestine, Texas.

Members of the Institute carry out observational programs with large-aperture telescopes in the far west. Data reductions and research with the plates are carried out at the Institute.

A program of postdoctoral resident research associateships is administered by the National Academy of Science's National Research Council and is supported by NASA. The most recent information indicates that approximately 20 research associates are in residence at the Institute. Graduate students from colleges and universities in the New York City area have offices and carry out research in the Institute. These students are supported by NASA grants to New York area universities for work in cooperation with Institute staff. An excellent research library at the Institute, stimulating colloquia and symposia, and informal contact with the members of the Institute serve to make it a valuable educational center for the area.

In addition to seminars given at the Institute, a number of Institute members give courses at the various universities and colleges in the New

York City area. All permanent Institute research staff members hold adjunct professorships with the local educational institutions.

Other training programs include cooperative summer institutes in space physics at college and high school levels, offered jointly with the Columbia University summer session, and a program in astronomy at postdoctoral level at the State University of New York at Stony Brook.

Since the establishment of the Institute in 1961, approximately 30 Ph.D. degrees have been awarded by universities in the New York area for research sponsored and supervised by the Institute's staff members. At the time of the site visit approximately 35 graduate students were working in space related research under staff supervision.

Future plans for the Institute include a cooperative venture with the State University of New York at Stony Brook and several other users to build a 60-inch metal-mirror telescope in the mountains south of Tucson, Arizona. Joint use of this instrument is planned by Institute staff members and the other groups. Because of the large number of students and staff at the participating institutions, one had the impression that the telescope will by no means fulfill the needs of the Institute in observational astronomy.

The major emphasis of the Institute is theoretical studies and only a few of the present staff members are involved directly in observational astronomy. As the other reports on institutions in the New York City area show, the Institute has been of great benefit to astronomy there. Indeed, the Goddard Institute ranks as one of the major astronomy efforts in New York State.

J. *Hunter College*

Hunter College of the City University of New York offers a strong undergraduate program in physics with additional courses in astronomy and astrophysics leading to a physics major. While no research instrumentation in astronomy is available at the college, excellent laboratory and demonstration equipment is available for use in the several courses in theoretical and observational astrophysics. One astrophysicist on the faculty, in collaboration with Columbia staff members, is actively studying the field of stellar interiors. The other, in association with staff members, at the National Aeronautics and Space Agency, is studying the statistical mechanics of galactic sized objects.

Future plans include the introduction of a graduate course in astrophysics and increased emphasis on the theoretical and observational

courses for training students. However, no major research projects at the college in astronomy or astrophysics are envisioned at this time.

K. *New York University*

The Department of Physics at New York University has four astrophysicists out of a total academic staff of 22. Work in solar astronomy and theoretical astrophysics is carried out in two centers of the University: the University Heights Campus in the Bronx and Washington Square Campus in Manhattan.

Studies in the physics of weak interactions and neutrino physics are applied to astrophysical problems by several staff members. Additional studies of convective heat transfer in stars, atmospheric oscillations, fluctuating magnetic fields, and the dynamics of various solar phenomena are also under study by one staff member. Observations with a high-dispersion Czerny-Turner spectrometer are carried out with the use of a small heliostat on the roof of Gould Hall of Technology on the University Heights campus. In these studies, the integrated light from the entire disk of the sun is used to feed the high-dispersion spectrometer. Thus observational studies of the sun as a star are being carried out with their instruments. This is one of the few research programs of this nature since most solar studies are carried out with high angular resolution on the disk of the sun. Other astrophysics related projects include balloon-borne cosmic ray detection packages which are flown from the national facility at Palestine, Texas. Studies of the variations of the proton flux with solar activity are being carried out in this project sponsored by NASA.

Complete facilities for computation are available at New York University. A CDC 1604 and an IBM 360 are located at University Heights and a CDC 6600 is located at Washington Square. In addition, graduate students and faculty frequently use the IBM 360/95 at the Goddard Institute for Space Studies for their research.

It was the opinion of several staff members interviewed that astrophysics is considered a branch of applied physics. Thus, no separate astrophysics program or department was envisioned. However, increased effort in the area of theoretical astrophysics was planned in the near future and several proposals in that direction were pending at the time of the site visit. Considerable value was placed upon the fruitful association with the Goddard Institute of Space Studies. A program of visiting professorships with European and other observatories will be continued.

L. *Rensselaer Polytechnic Institute*

Located in Troy, New York, RPI has a strong program in physics and astronomy research supported mainly by the National Science Foundation and RPI. Four astronomers and a physicist (on a part-time basis) are active in the research and teaching programs. In the fall of 1968, 12 graduate students were conducting their thesis research in astronomy. Three doctorates have been granted in astrophysics. Both the Doctor of Philosophy and the Master of Science degrees are given. Research areas of the department fall in the fields of nuclear physics, solid state physics, and astronomy.

A major research program of laboratory experiments on the scattering of microwaves by small objects is related to the analogous problem of light scattering from interstellar dust. This important program of laboratory astrophysics allows studies of complex scattering properties of particles which are sealed up in size in proportion to the relative wavelengths of light and microwaves. The polarization and directional scattering properties of the model particles are studied with movable receivers in the laboratory. Not only do the experiments provide research results which are unique and difficult to duplicate mathematically, but they also help determine new directions in which to proceed with theoretical model calculations. Such calculations are also being carried out at RPI.

The International Astronomical Union recently held a special meeting at RPI for the discussion of research in the field of light scattering by small particles. The meeting was attended by experts in the field from all over the world. Certainly RPI can be considered an important center for research in the field of interstellar particles.

Equipment at RPI includes a 12-inch reflecting telescope equipped with a photoelectric photometer, used to instruct students. The computing laboratory of the Institute houses an IBM 360/50. In addition, the Physics Department has an IBM 1620 computer, which is available for part-time general calculations and is used part-time on line in an X-ray crystallography experiment.

A considerable astronomy and astrophysics library is available at RPI in addition to a set of prints of the Palomar Sky Atlas. However, students and staff must utilize observational and data reduction equipment at the National Observatories at Kitt Peak and Greenbank for most dissertation research.

Efforts have been made to obtain a telescope of intermediate size. Considerable concern over the lack of such telescopes in New York State was expressed at RPI. Such instruments (reflectors of approximately

40-inch aperture) would be of great use in training students and in carrying out small experimental projects in astronomy. Aside from the efforts to obtain a small research quality telescope, no plans for expansion of the existing program were mentioned at the time of the site visit.

M. *Rochester Institute of Technology*

The new campus of the Rochester Institute of Technology is located on the southern outskirts of Rochester, New York. The astronomy courses are offered at the fourth year level in the School of General Studies. No major in astronomy is anticipated at this time. Plans to continue with a small instructional program as an elective in the fourth year are under consideration. Cooperative use of the community planetarium in an introductory course is planned.

N. *State University of New York at Albany: Dudley Observatory*

The newly formed Department of Astronomy and Space Science at SUNY at Albany has joined forces with the venerable Dudley Observatory to produce a strong and rapidly developing astronomy program. Offices for the Department of Astronomy are housed in the magnificent new buildings at SUNY at Albany. Additional research facilities and office space is provided at the new Dudley Observatory building, which is part of a modernized warehouse.

The staff, in the fall of 1968, consisted of nine academic faculty including one visiting professor. Six major programs exist at SUNY at Albany: planetarium studies; space science including research on cosmic microparticles; spectroscopy and photometry of stars; stellar distributions; studies in theoretical astrophysics including stellar interiors and atmospheres; radio astronomy and solar physics both from the observational and theoretical points of view.

The planetarium remains in the proposal stage after some efforts over several years to construct a major facility. The proposed program would involve a major Zeiss projector in a large dome and a program of planetarium instruction. A program in science education with emphasis on planetaria is also planned.

The major area of experimental research at the observatory is presently space science. Micrometeorites are collected using sounding rockets, balloons, and manned space capsules. Electron microscopy of the micron-sized particles enables the scientists to study the nature of cosmic dust. The composition of the particle can also be studied with these techniques. Several "clean room" facilities are available to insure that

samples recovered from the spacecraft and probes are indeed extraterrestrial in origin.

Spectroscopy and photometry studies are carried out at Kitt Peak National Observatory and at Cerro Tololo Inter-American Observatory in Chile. Studies in galactic structure and on clusters of galaxies are made using objective prism plates and direct photoelectric photometry. The Department is making a name for itself through its work on the distribution of stars at some distance from the central plane of our galaxy. Data reductions and production of research papers are carried out at the Dudley Observatory offices.

A program in theoretical astrophysics is just beginning with two professors planning major research programs in the fields of stellar interiors and stellar atmospheres. At the time of the visit, a new computer center for the University was in the construction phase. The final area of research at the University, solar physics, involves one of the permanent staff members and a visiting professor. Observations of the sun have been carried out with solar telescopes at Kitt Peak National Observatory. The research involves studies of the depth dependence of turbulence in the sun.

Research equipment at the Observatory includes a considerable amount of data reduction equipment. A new Mann 2-screw measuring engine with digitized output and large darkroom facilities are available. An iris photometer is used to measure the brightnesses of star images on photographic plates. The only telescope presently available is an old 12-inch refractor housed at the original Dudley Observatory site.

There are solid plans for expanding the research facilities. In particular, a 40-inch telescope is under serious consideration. In space science, some Apollo Applications Program projects are in the planning stage. There were six graduate students in degree programs in the fall of 1968. The Ph.D. program in astronomy had just been instituted this fall.

A stimulating climate for research in astronomy exists in the Albany-Troy area with the staffs at Rensselaer Polytechnic Institute and State University of New York at Albany complementing each other.

O. *State University of New York at Binghamton*

The Department of Physics at SUNY at Binghamton offers undergraduate courses in astronomy as part of the physics curriculum. No research or graduate study in astronomy is presently available at the university. The physics group has just moved into a new science center

building which also houses the Chemistry Department. This building is well equipped and includes some laboratory facilities for the astronomy courses. Some courses in relativity theory are taught in the Master's physics program. Several department members show interest in the astronomical aspects of relativity.

The community of Binghamton has an active amateur group of astronomers and a new planetarium. The university has offered help in site preparation for a small telescope which the amateur group may soon erect. However, this instrument will be used only in connection with the Descriptive Astronomy course. At the present, no plans for expansion into astronomy are envisioned. However, considerable interest in the activities of the New York Astronomical Corporation was expressed.

P. *State University of New York at Buffalo*

The Department of Physics and Astronomy at SUNY at Buffalo carries out no research activities in astronomy at present. Support for the astronomy instructional programs comes entirely from the University supported physics program. However, the chairman of the department expressed considerable interest in possible future astronomy/astrophysics programs. He, together with the Provost of the University, who also serves on the faculty of the College of Engineering and Applied Science, has proposed extensions of the physics-astronomy program and the addition of several theoretical astrophysicists to the department. Cooperation in the "Camroc Project" with M.I.T. and Harvard is also envisioned. This project would involve moving the Harvard 60-foot radio telescope to the Buffalo area, where it would be used in coordination with others in Massachusetts and Toronto, Canada. This cooperative effort would make possible very long base line interferometry experiments as described in the section on the Arecibo telescope.

The addition of an astrophysics and radio astronomy program will undoubtedly await the move to facilities included in a new campus now under construction.

Q. *State University of New York at Stony Brook*

The Department of Earth and Space Sciences at SUNY at Stony Brook includes a newly formed astronomy group housed in the new Earth and Space Science Building on their Long Island campus. Efforts in theoretical and observational astrophysics are rapidly developing. Staff members carry out research in the fields of photometry of galaxies;

stellar atmospheres; gravitational collapse in highly evolved stars; geo-astrophysics; photometry and evolution of stars in the galaxy; galactic structure; quantitative spectrophotometry; and problems of the interstellar medium. It is planned that two or three staff members will be added in astronomy during the coming year. Theoretical calculations are carried out on the IBM 360/67 at Stony Brook and the IBM 360/95 at Goddard Institute for Space Studies.

A full program of undergraduate and graduate degrees in astronomy and astrophysics is offered by the university. The present complement of graduate students is six. The goal of the department for 1972 is nine to 12 faculty members for approximately 30 to 40 graduate students. The present staff includes six academic staff in the astronomy program. It is hoped that the need for additional postdoctoral fellowships may be met.

A major effort is being made by Stony Brook and other institutions to correct the deficiency of observational facilities and opportunities for data gathering characteristics of most East Coast schools. Two 60-inch reflecting telescopes will become available for part-time use by the staff at Stony Brook. Both of these telescopes will be located on clear mountain sites near Tucson, Arizona. One of the instruments is supported by NASA and the University of Arizona. The other jointly operated telescope has major support from the Smithsonian Astrophysical Observatory. In addition to the western telescopes, a 16-inch reflecting telescope will be located on the campus for training students and for use in research projects which do not require totally clear skies.

There are substantial reasons for the planned use of these telescopes in Arizona. National Observatories at Kitt Peak and Cerro Tololo provide modern instrumentation for observational astrophysics. However, in order for proposals to be accepted on these telescopes, they must be programs of rather short duration with a high probability of success. In order to allow Stony Brook staff members a wider range in selection of observational instrumentation and problems, the 60-inch telescopes in Arizona will be used for long-term projects and for experimental projects which could not ordinarily be tried at the National Observatories. The program chairman placed considerable emphasis on the need for travel funds to enable faculty to travel freely to clear observing sites.

Two summer institutes in past years have been very successful. Distinguished astronomers gave lectures to a limited number of students about their area of research interest. The discussions have proven very stimulating for professor and student alike. Another such institute is planned for the summer of 1969.

R. *Syracuse University*

The Department of Physics at the University of Syracuse offers a descriptive astronomy course and a number of graduate courses in astrophysical areas. Selective topics of astrophysics, atomic and molecular spectra, and the theory of relativity are taught in various graduate level courses. However, no undergraduate or graduate degrees in astronomy or astrophysics are offered.

The university has an 8-inch Clark refractor made in 1887, which is used for demonstration purpose for the Descriptive Astronomy course. No research equipment for the telescope is available.

The university computing facility has an IBM 360/50 computer. The Physics Department has a departmental computer budget for the use of faculty and students on dissertation projects. The Chairman of the Physics Department is a specialist in infrared spectroscopy and infrared instrumentation. Other department members carry on research in the area of relativity theory.

A major future plan of Syracuse University is an effort to obtain private funds for a chair of astrophysics. The program would involve one senior astrophysicist, one assistant professor, and some related support staff for a total of about six people. The department presently has eight professors in the research area of high energy particle physics and six professors in the area of solid state physics. The annual Ph.D. production in Physics is approximately 10. The Descriptive Astronomy course at Syracuse University fulfills a secondary science requirement for liberal arts majors.

S. *The University of Rochester*

The University of Rochester is presently completing a new Space Science Building which will house the astronomers and cosmic ray physicists of the Department of Physics and Astronomy. The program at Rochester is distinguished by effective cooperation among the faculties of physics and astronomy and other departments in the University.

The largest telescope in the State of New York is housed in a dome approximately an hour's drive from the university campus. It is a new 24-inch aperture cassegrain reflector at the C. E. Kenneth Mees Observatory. This is a modern telescope with modified German mounting. It is presently used in programs of photometry, spectroscopy, polarimetry, and direct photography utilizing a cascaded image converter. In addition to the Rochester staff, some guest investigators from outside institutions have used the instrument.

The staff uses an IBM 360/65 computer for theoretical studies and for data reductions. Other equipment at the observatory or in the Astronomy Department includes an iris photometer for photometry of stellar photographs and a two-coordinate measuring engine. A Fabry-Perot spectrometer is available for infrared studies.

Five full-time astronomers constitute the present staff in the Department of Physics and Astronomy. In addition, members of the physics faculty also participate in astronomical projects. At present, approximately 15 graduate students are working on masters or dissertations projects. There is a strong undergraduate curriculum in astronomy but relatively few majors graduate each year in astronomy.

One staff astronomer has used telescopes in California, at Kitt Peak National Observatory, and at Cerro Tololo Observatory in Chile for studies of RR Lyrae stars in the Sagittarius II Association. A search for the optical counterpart of the pulsar CP 1919 was carried out by a group of physicists and astronomers using the 24-inch Mees telescope. One of the astronomers is conducting theoretical studies on models of pulsars. He has shown that the periods of envelope pulsations of white dwarfs are comparable to the observed periods of the pulsars. Other theoretical studies at the Observatory include investigations of plasma oscillations in an extended plasma with the ultimate results bearing on the theory of cosmic sources of radio emission.

Numerous observational projects are undertaken by the five staff astronomers. This department at the University of Rochester represents one of the most well-balanced programs in observational and theoretical astronomy in the State of New York. Staff members not only use optical telescopes, but occasionally use the facilities at the national Radio Astronomy Observatory.

Important studies of emission nebulae and the spiral structure of our galaxy have been carried out by the Director of the Mees Observatory. Image-converter photographs have been obtained of a peculiar galaxy which shows a pronounced nuclear bulge and a substrate of red stars. The image converter has also been used to study the polarization of the light of faint stars in the vicinity of pulsar CP 1919.

One staff member recently published an extensive study of the abundances of the elements in 27 cool giant stars. Theoretical studies by other staff members and recent dissertations have been in the field of the origin and evolution of planetary nebulae and models for pre-white dwarf stars. The Chairman of the Department, a physicist, has been carrying out cosmic-ray observations utilizing balloon-borne detectors. A second program of gamma-ray astronomy using balloon-

borne spark chambers was completed recently and further studies of gamma-ray astronomy are being carried out on scientific satellites.

T. *Vassar College*

Vassar's observatory is equipped with a first class library and a 15-inch reflecting telescope of modern design. The Department of Physics and Astronomy has two professors (one an astronomer), one associate professor, and two assistant professors. A major in astronomy is offered and several Vassar graduates have continued through the Ph.D. at other institutions and are presently contributing to research astronomy. The astronomer at Vassar carries out research on the discovery and study of high liminosity stars using objective prism spectrograms obtained with the 24-inch Schmidt telescope of the University of Michigan located at Cerro Tololo Inter-American Observatory in Chile. The college provides IBM 360/30 computer time for the use of this astronomer in his research and teaching.

Future plans at the college include a possible second faculty member in astronomy. However, the philosophy of the college seems to remain that of a small liberal arts school so that expansion into graduate programs is not presently anticipated.

U. *Yeshiva University*

Yeshiva University and its division, the Belfer Graduate School of Science, have recently started a program in space physics with special emphasis in the area of astrophysics. At present there are two astrophysicists on the staff and two research associates directly involved in the same research areas. An additional staff member spends approximately one-third of his time in nuclear astrophysics. Approximately seven students are presently at various levels in their graduate programs in nuclear astrophysics and physics.

Computations are carried out primarily at the Goddard Institute for Space Studies in New York using the IBM 360/95 computer. These studies are supported by grants from the National Aeronautics and Space Administration, the Atomic Energy Commission, and the National Science Foundation.

At present no experimental astrophysics programs are being carried out at Yeshiva. However, the university graduate school plans a new building for the physical sciences which will offer the possibility for experimental research in physics. The primary astrophysical area of research in the department will remain in nuclear astrophysics with the aid of calculations carried out on large computing equipment.

Chapter IV Suggestions for Future Development

Astronomy in New York State, as the reports show, is highly diversified. Some public and privately supported institutions have strong, excellent astronomy programs. Many schools with strong physics departments wisely see the value of growing interaction with astronomy.

The truly outstanding research in New York State is being done in theoretical astrophysics and in radio astronomy; the same level has not been attained in optical astronomy. Most of the astronomers and physicists visited, asserted that better research facilities, centering on a major optical telescope, were essential to continued growth in all areas of astronomy and astrophysics in the State. Not only would improved optical observational facilities aid the programs of astronomers now in the State, but would be vital to attracting and holding other distinguished astronomers working at the research frontiers in both theoretical and observational fields. It is one thing to have the discoverer of the quasars "down the hall"; it is another to read about this work in a condensed journal version 6 months later. In addition, the best prospective graduate students in this field would be increasingly attracted to New York State's institutions.

It is the author's opinion that if one were to consider what would be most necessary for New York State's continued growth and increased excellence in astronomy, it would, without question, be the acquisition of a large optical telescope. An instrument of the 150-inch class (located in the best possible site) would be most desirable. A larger telescope could incur increased engineering costs and development time, which would cancel advantages to be derived from such an instrument.

A balanced observatory program would require that this large telescope be supplemented by an 80-inch reflector of similar design and f-ratio so that accessory instrumentation could be used on either instrument. A wide-field Schmidt type telescope with objective prism and with an aperture in the range of 24 to 40 inches would complete the necessary equipment. Experience at Mt. Palomar and Kitt Peak shows that the smaller telescopes could serve as survey and "finder" instruments for the larger telescope. In addition, many complete programs could be carried out with the smaller instruments alone.

The large instrument should be of general usefulness, not a "special purpose" telescope for one project only. It should be useable for direct photography, photometry, and cassegrain/*coude* spectroscopy throughout the entire spectral range of the "optical window" of light transmitted by the earth's atmosphere.

The importance of locating the observatory where the greatest number of clear nights per year are available cannot be overemphasized. The best location would probably be in the Southern Hemisphere; the advantages of the La Serena area of Chile have been discussed earlier in this report. It makes available the great unexplored areas of the southern sky with excellent viewing conditions. Modern practices of data gathering, transmission, and treatment reduce to a truly negligible level any apparent disadvantages of distance between an observatory and the institution it serves. Travel and transportation costs for personnel and supplies have been shown to be an inconsequential fraction of the total programs in astronomical research.

An experienced director should be chosen to oversee the project. He could draw on the engineering, astronomical, and administrative talent already in existence at the various academic and corporate institutions in the State, but he would be ultimately responsible for the successful completion of the project. An example of the type of experience the director might draw upon is that of the Cornell Center for Radiophysics and Space Research in the operation of their 1000-foot radio/radar telescope in Puerto Rico. The administrative and logistical problems of a remote observatory operation have already been faced and solved by the Cornell group. It is strongly recommended that supervision of such a project should *not* be provided by a committee.

Additional copies of this report (OST-7) may be obtained from:

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